Vol. 17, No. 2 **MAY 1996**

GEO-HEAT CENTER QUARTERLY BULLETIN

ISSN 0276-1084
A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS

Cover: **Beppu Jigokus**. Jikokus or "Hells" are famous hot springs in Beppu, Japan, that are popular tourist attractions. In the upper left is **Umi Jigoku (Sea Hell)** so called because this jigoku looks like the sea, which emerged after an explosion of a volcano 1,200 years ago and because the color of the boiling water of the pond is cobalt-blue. **Chinoike Jigoku (Blood Pond Hell)** is the oldest natural jigoku in Japan, and the pond is blood-red in color. In the lower left is **Bozu Jigoku (Bonze Hell)** which was formed about 470 hears ago when a severe earthquake occurred resulting in an eruption under a temple. **Hotta** is a well site (left on the lake) for the district heating system. The wells require daily reaming to remove scale build up.

PUBLISHED BY

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All articles for the Bulletin are solicited. If you wish to contribute a paper, please contact the editor at the above address.

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FUNDING

The Bulletin is provided compliments of the Geo-Heat Center. This material was prepared with the support of the U.S. Department of Energy (DOE Grant No. DE-FG07-90ID13040). However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the view of USDOE.

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BEPPU HOT SPRINGS

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INTRODUCTION

Beppu is one of the largest hot springs resorts in Japan. There are numerous fumaroles and hot springs scattered on a fan-shaped area, extending 5 km (3.1 miles) from east to west and 8 km (5.0 miles) from north to south. Some of the thermal manifestations are called "Jigoku (Hells)", and are of interest to visitors. The total amount of discharged hot springs water is estimated to be 50,000 ton/day (9,200 gpm) indicating a huge geothermal system. The biggest hotel in Beppu (Suginoi Hotel) installed a 3-MW geothermal power plant in 1981 to generate electricity for its own private use.

BEPPU JIGOKUS

There is a worldwide interest in a special kind of jigokus or "hell" found in Beppu--the city's famed natural steaming hot springs. Beppu's most unusual sightseeing attractions are eight jigokus. The word "jigokus" originates from the "burning hell" of the Buddhist sutras, and the Beppu jigokus truly remind one of "burning hells." The Bozu jigoku, contains boiling gray viscous mud which bubbles incessantly with a menacing sound. More attractive jigokus to be seen in around Beppu are the Umi jigoku, or Sea Hell, contains white particles that reflect the color of the sky. Another, the Chinoike, or Bloody Pond, has a vermillion color. Tatsumaki jigoku (water-spout hell) is a geyser which forcefully shoots up water to a height of 20 meters (82 ft) every 25 minutes.

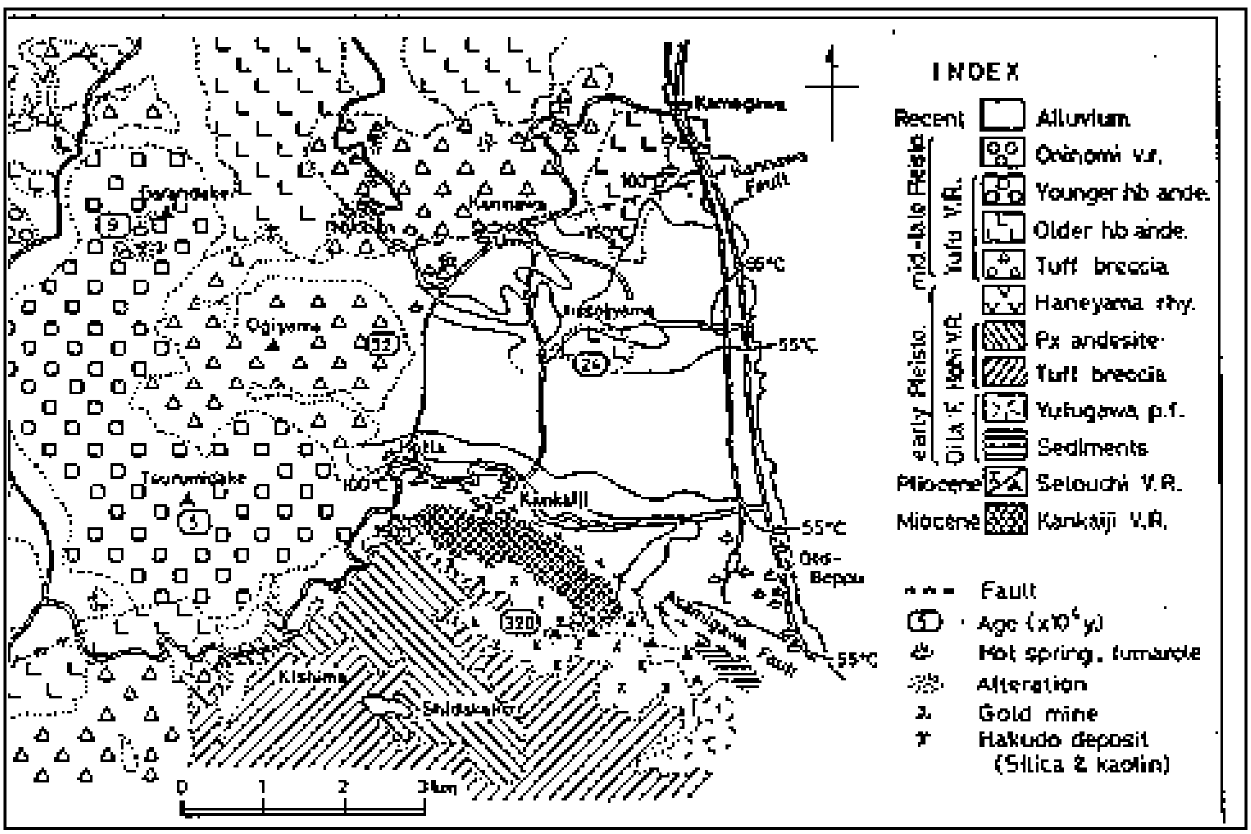

Figure 1. Geological map of the Beppu geothermal area, partly modified after Hayashi and Taguchi (1987). Temperature contours at 200 m below surface are from Kikkawa (1972). Sg = Suginoi geothermal power station, Ch = Chino-ike Jigoku, Um = Umi Jigoku, Bz = Bouzu Jigoku.

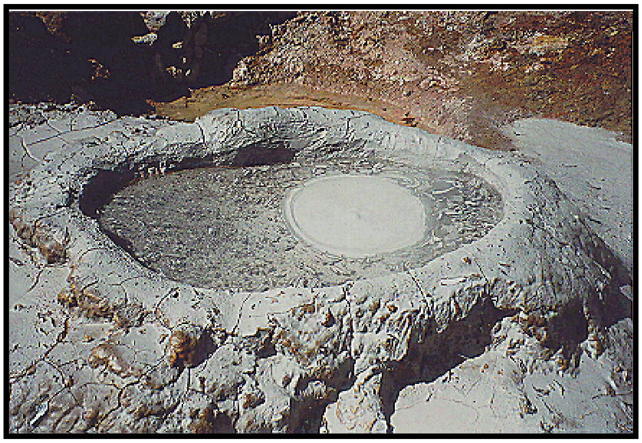

Figure 2. Bozu jigoku.

Figure 3. Chinoike jigoku.

One of Japan's most popular hot springs resort cities, Beppu is tucked between a bay of the Inland Sea and two dormant volcanoes on the edge of the Island of Kyushu. Hot water is the keystone of Beppu's tourism; but, it also plays an important part in the daily lives of the city's residents. Steam from wells is used to heat water which is delivered by pipes to homes and businesses. Some of it goes into homes and restaurants for cooking vegetables. The water is also used for agricultural research, physical therapy and of course, recreational bathing.

Figure 4. Beppu residence.

Bathing has long been a national passion in Japan. Even if there is a bath at home, the family often goes out to soak with friends and strangers at a public bathhouse. There are baths for every pocket book in Beppu, and the municipality itself runs several especially for poorer residents.

The majority of Beppu's *onsens*--hot springs baths--cater to a clientele ranging from vacationers at posh hotels to workers stopping by to clean up before going home. Since there is little central heating in Beppu and elsewhere in Japan, the baths serve some people as a warm and cozy refuge during the long gray winters. The number of amenities provided at a Japanese hot springs bath do not alter its basic properties. First and foremost, it is *very hot*--usually kept between 41ºC (105ºF) and 48ºC (118ºF). Cooling or diluting the water at Beppu is often necessary because the springs range from 50 - 100ºC (120 - 212ºF). The Japanese bath is more a place for soaking than for scrubbing. No bather would think of entering the pool without first washing his entire body and rising it. In fact, relaxation is the bather's primary goal.

Figure 5. Production well site for steam injection into distribution system.

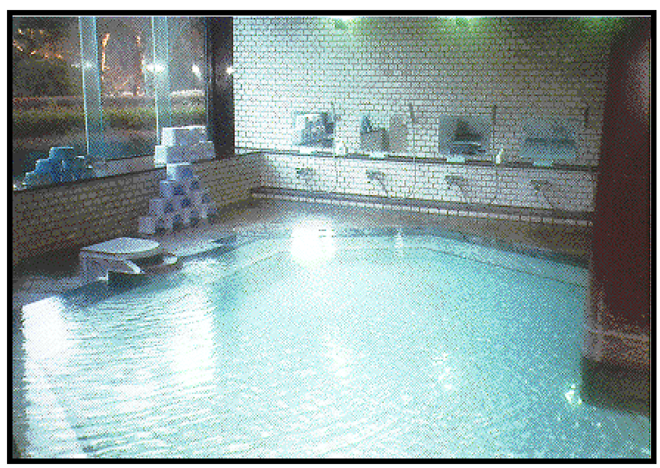

Figure 6. Japanese bath.

At Umi jigoku, which is much hotter than the bathing springs, piped steam heats a large banana greenhouse alongside the pond. At another steam vent, more than 900 tons/day (238,000 gal/day) of water bubble out in a garden of a Buddhist statuary. A small zoo has been constructed around the Yama jigoku, and the animals that drink and wallow in the warm water include hippopotamuses, monkeys, snakes and pelicans. Nearby, as at other jigokus, attendants constantly hard-boil eggs in the water, and vendors sell cans of powdered mineral sediments for use in tubs at home.

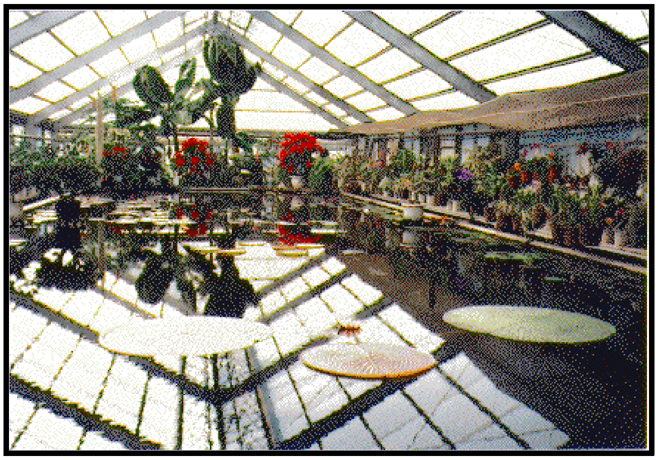

Figure 7. Umi jigoku (Sea Hell) greenhouse.

Geothermal water also is used in several agricultural research facilities like the Oita Research Station for Agricultural Utilization of Hot Springs. There, the mineral water irrigates and heats vegetable, fruit and flower greenhouses all year. Experimental crops of tomatoes, cucumbers and eggplant are harvested regularly along with bananas, mangos, papayas and other tropical fruits. There's also extensive research on the breeding of plants and shrubs such as azaleas, camellias, rhododendrons and carnations.

GEOLOGY

Beppu is located at the eastern end of the Beppu-Shimabara Graben. The basement rocks are probably the same as those of the Hatchobaru geothermal field: Paleozoic crystalline schists and Cretaceous granite intrusions. This is based on the fact that such rocks are found as xenoliths in rocks such as the Yufugawa pumice flow, the Hohi volcanic rocks and the Yufu volcanic rocks and formations (the Kankaiji and the Setouchi volcanic rocks, Oita formations, and Hohi volcanic rocks in ascending order) are mainly situated in the southern part of the field (Figure 1). The middle-to-late Pleistocene Yufu volcanic rocks (<0.32 Ma) form lava domes of hornblende andesite such as the Tsurumi-dake and the Yufu-dake, located to the west of the field. Fission track ages of the domes are younger than 100,000 years, and the heat source of the area is probably related to the post volcanic activity of the domes.

GEOTHERMAL SYSTEM

There are various type of active geothermal manifestations: hot springs, hot pools, mud pools,geysers and fumaroles. Those are mainly distributed along and/or around the Asamigawa fault to the south and the Kannawa fault to the north (Figure 1). Steaming ground and advanced argilic alteration zones (Hakudo deposit) are dominant at Myoban, west of the Kannawa fault.

Table 1. Typical Chemical Compositions of Hot Springs in Beppu

Area Name	Kannawa Ishimatsu	Kannawa Chinoike	Myoban Yamadaya	Kamegawa Shinoyu	Old-City Kimura	Hotta Hotta	Kankaiji Jizouyu
Temp.	100	60	67.5	56.6	55.6	75.5	50
pH	7.7	2.4	1.7	8.2	7.4	6.2	6.9
Na^+	882	700	24.1	182	170	26.78	30
K^+	97.8	103	16.7	28.6	14.1	3.438	5
Mg^{2+}	1.0	17.6	10.2	6.6	33.2	12.22	12
Ca^{2+}	24.5	42.0	26.0	20.4	47.5	17.91	57
Al^{3+}	0.1	2.28	203	0.1	0.1	0.12	
Mn^{2+}	0.4	4.3	0.4			0.005	
Cl^-	1104	1003	5.7	225	107	17.88	3
SO_4^{2-}	455	570	1649	152	53.4	66.05	45
HSO_4^-			1108				
HCO_3^-	49			108	504	76.25	188
$HAsO_2$	1.63	1.3		0.7	0.21		
H_2SiO_3	506	299	411	198	252	112	126
HBO_2	39	72	49.9	15.8	4.7	22.7	
Ref.	1	2	1	3	1	4	5

Ref. 1: Oita-ken (1982), Ref. 2: Koga (1972), Ref. 3: Oita-ken (1984), Ref. 4: Oita-ken (1970), Ref. 5: Koga (personal communication).

The chemistry of hot spring waters is rich in variety (Figure 8 and Table 1): sulfate-rich steam heated water (at Myoban), chloride-rich deep water (at Kannawa), bicarbonate-dominant water (Old Beppu), and their intermediate types (at Kamegawa, Hotta and Kankaiji).

Chemically estimated subsurface temperatures in Beppu are shown in Figure 9. High temperature zones above 200°C are distributed at Myoban, Ogura, and Kannawa along the Kannawa fault to the north, and also at Hotta-Kankaiji along the Asamigawa fault to the south. The Suginoi geothermal power station is located on the latter fault. However, cooling also seems to have occurred from the southeast along the same fault (Figure 1).

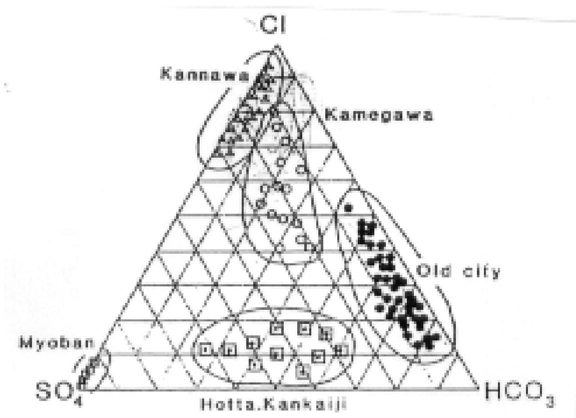

Figure 8. Chemical compositions of Beppu hot springs waters (Koga, 1985).

Among the many Jigoku, the Chino-ike Jigoku (Blood-pond hells) is perhaps the most spectacular, since its color resembles that of blood, due to the red precipitates. This Jigoku is a hydrothermal eruption crater (Figure 10), and eruptions were recorded nine times during the period from 1875 to 1927 (Yoshida, et al., 1978). Total output of hot water from the crater is 100 l/min (23 gpm), and the maximum temperature is 136.8°C (278°F) at the bottom (-26 m, -85 ft). The chemistry of the water suggests a blend of sulfate-rich water (SO_4 = 604 mg/l) and deep chloride-rich water (Cl = 1,002 mg/l). The red precipitates are rich in heavy metals (Au = 23, Ag = 383, As = 4,440, Sb = 180, Pb = 442, Zn = 104 and Cu = 57 ppm respectively), and consist of low cristobalite, tridymite, kaolin, hematite, and montmorillonite (Koga, 1972; Yamashita, 1977; Yoshida, et al., 1978).

Gold and silver were also reported from other Jigoku and hot springs in the Kannawa area: Yunohara, Umi, Kyuman, Raisen, Shibaseki, and Honbouzu (Koga, 1961). Epithermal gold veins, embedded in the Kankaiji volcanic rocks, were once mined in small scale south of Kankaiji. There was, however, some trouble with steam discharge.

According to the recent work on the Beppu geothermal system (Allis and Yusa, 1988), the characteristics of the thermal manifestations are interpreted using a simple model as shown in Figure 10: the main steam loss with minor dilution occurs along the Kannawa fault and the major dilution with minor steam loss along the Asamigawa fault. Koga (1987) also proposed similar fluid paths according to the hot water chemistry.

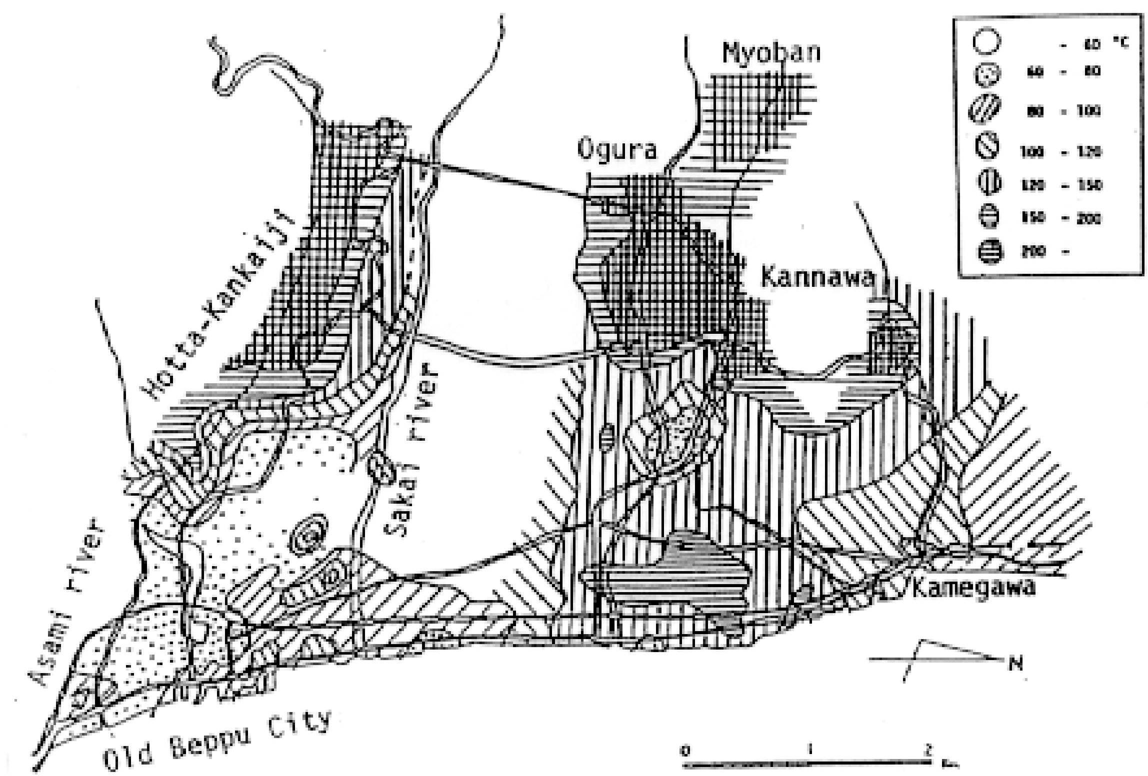

Figure 9. Chemically estimated subsurface temperature distributions in Beppu (Koga, 1987).

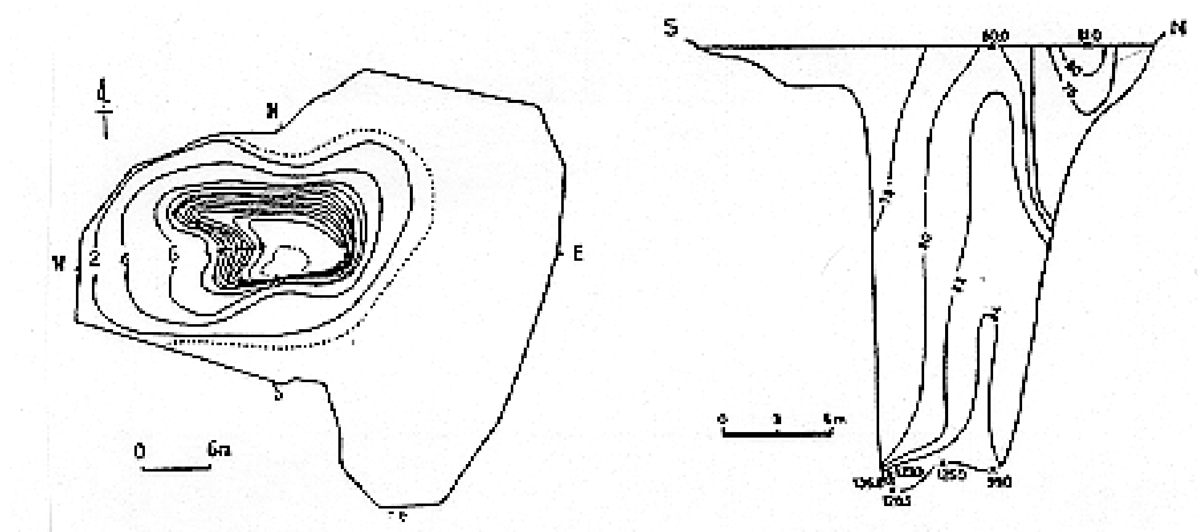

Figure 10. Isobath of the Chino-ike Jigoku in meters (left), and cross section of the Jigoku (right) showing temperature profiles in ºC (right) (Yuhara, et al., 1978).

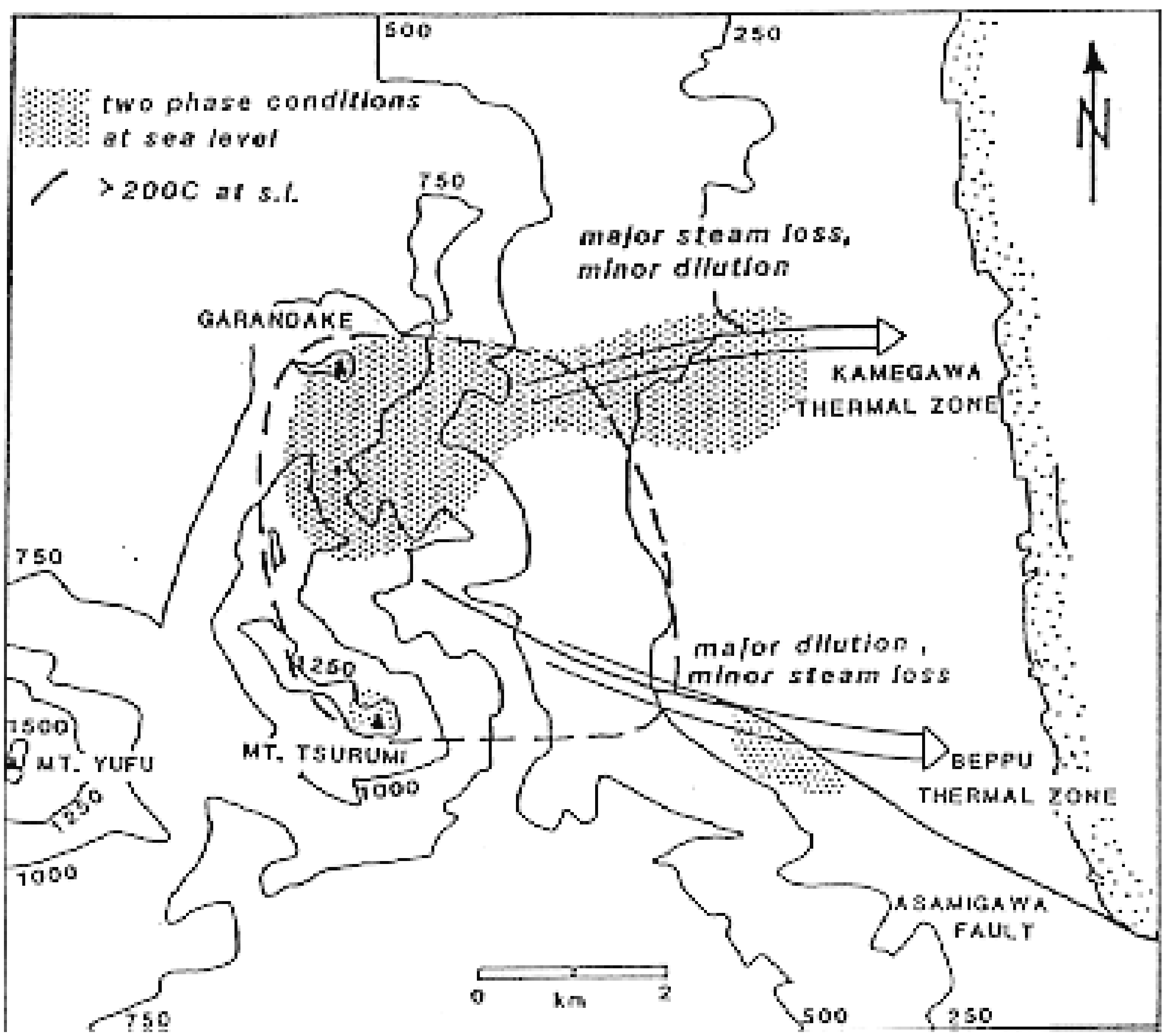

Figure 11. Identification of the main fluid flow processes in the Beppu geothermal system (Allis and Yusa, 1988).

EDITOR'S NOTE:

Paul Lienau and John Lund of the Geo-Heat Center had the opportunity to visit Beppu's most unusual sightseeing attractions, four of eight jigokus in this paper. Beppu is one city being considered for the World Geothermal Congress 2000.

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3,000 kW SUGINOI HOTEL GEOTHERMAL POWER PLANT

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Beppu Suginoi Hotel
1 Kankaiji
Beppu 874

INTRODUCTION

The Suginoi Hotel is located, 200 m above sea level, in Beppu City, which is one of the largest hot spring resort area in Japan. In this hotel, there are some unique hot spring baths, which are interesting to visitors. In Beppu, there are numerous hot springs, some are call "Jigoku" (Hells). The main attraction in Beppu are the hell-like spots created by hot springs such as the Torando Hell, which erupt to a height of more than 50 meters, the Blood Pond Hell which is bloody red due to red clay content.

In yield, these hot springs rank second in the world next to those of Yellowstone National Park in the USA.

HOT SPRINGS

The hot springs in the Suginoi Hotel are colorless and transparent, and have a slight sulfur odor. They are at an ever constant 210ºC. The ingredients in one kg of this mineral water are (mmg):

Chrome	2,174	Hydro carbonic acid	99,860
Sulfuric acid	71,660	Nitrium	31,350
Hydro acid	0.355	Calcium	48,870
Meta boric acid	6,552	Magnesium	13,190
Carbonic acid	36,210		

The Suginoi Hotel, consisting of two towers, has a capacity of 2,100 guests, 11 meeting rooms, 20 banquet halls, 4 restaurants, 4 cafeterias and a wedding ceremonial room. The hot springs are also used for Acquabeat (Figure 1), a facility that includes water slides, jacuzzi, dream bath (Ume-no Onsen), flower bath (Hana-no Onsen), outdoor hot spring baths, a wave pool, theater, bowling alley and restaurant.

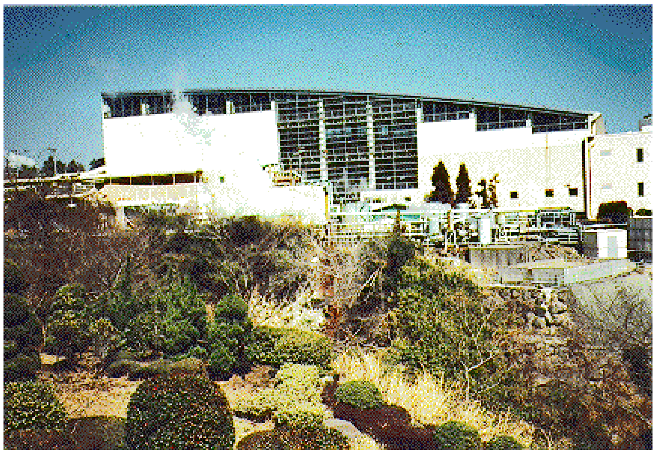

Figure 1. Acquabeat facility.

GEOTHERMAL POWER PLANT

A 3,000 kW geothermal power plant was put into commercial operation in November 1980 to supply electricity for the hotel use. The geothermal energy is utilized for many purposes such as baths, hot water supply, space heating and air conditioning as well as for power generation.

Figure 2. Steam separator.

OUTLINE OF THE 3,000 kW SUGINOI GEOTHERMAL POWER PLANT

Location	2272 Minamitateishi, Beppu City
Area	38,000 m^2
Rated output	3,000 kW
Construction start	October 1979
Operation start by back pressure	November 1980
Operation start by condensing	March 1981
Annual generation	18,000,000 kWh (approx.)

Steam Gathering Plant

Geothermal steam from the three wells is collected in a steam gathering plant located beside the power house through a two-phase flow transmission pipeline. The steam gathering plant consists of a cyclone separator and a moisture separator, and supplies clean steam to the turbine. Also, waste hot water from the steam gathering plant is utilized for public use such as baths in Beppu.

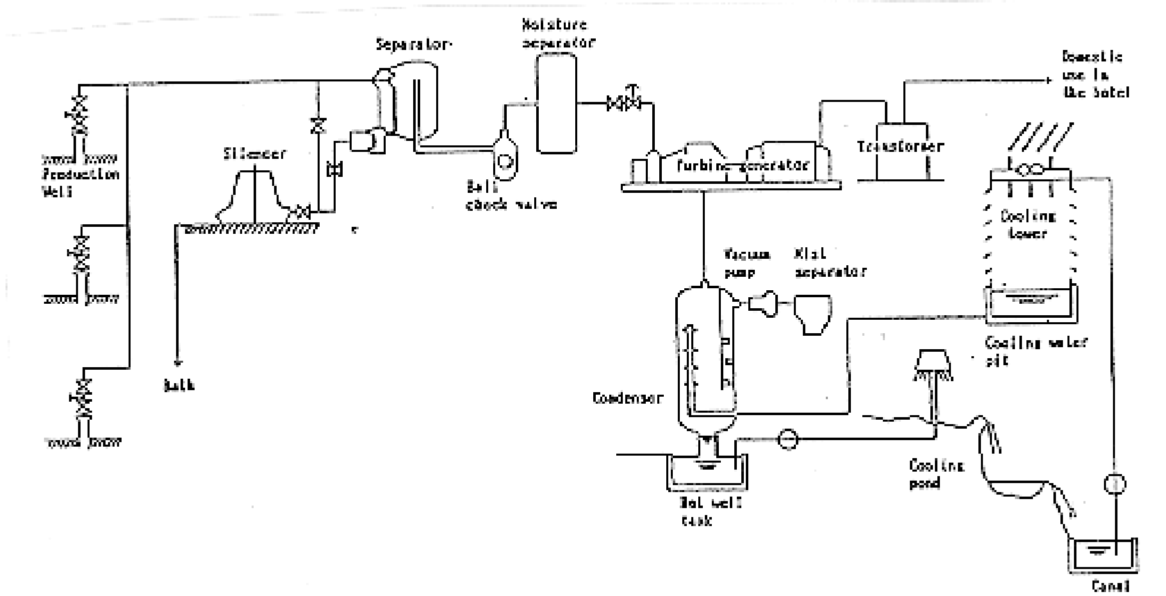

Figure 3. Schematic diagram of 3,000 kW Suginoi geothermal power plant.

Steam Turbine

Type	Condensing turbine
Output	3,000 kW
Steam condition	(main stop valve inlet)
Pressure	4.0 kg/cm^2 abs
Temperature	142.9ºC (saturated)
Exhaust pressure	0.3 kg/cm^2 abs
Steam consumption	40,000 kg/hr

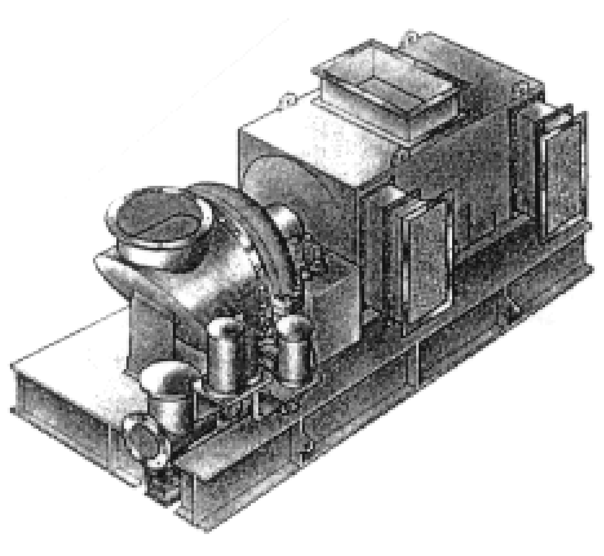

Figure 4. The Mitsubishi portable turbine generator.

Generator

Type	Open-circuit, air-cooled generator
Capacity	3,530 KVA

Condenser

Type	Spray-tray, barometric-type jet condenser
Vacuum	0.3 kg/cm^2 abs
Cooling water	Recirculating water
Temperature	32ºC
Quantity	600 m^3/hr

Gas Extractor (22 kW x 2, 37 kW x 1)

Type	SONIT-TV
Diameter	100 mm (150 mm)
Vacuum	547 mm Hg
Quantity of gas	10(20) m^3/min

Cooling Tower

Type	Mechanical draft counter flow type
Capacity of cooling	21,000,000 Kcal/h
In/Out temperature	32 ~ 67ºC
Wet bulb temperature	27ºC
Circulation water quantity	600 t/h
Cooling tower fan	1 kW x 4

Warm water from the condenser is first cooled at the cascade cooling pond, which also serves as a sightseeing spot, and is further cooled in the cooling tower. Then, the cooled water is reused for cooling water.

GEOTHERMAL GREENHOUSES IN KYUSHU, JAPAN

Paul J. Lienau
Geo-Heat Center

INTRODUCTION

The New Energy Foundation (NEF) invited two members of the Geo-Heat Center staff to Tokyo to present two workshops on the direct uses of geothermal energy in the United States. Prior to the meetings, a field trip was arranged by NEF to visit geothermal power plants and direct use sites on Kyushu. Seven areas were toured on February 27 and 28th, including the Sensui Rose Garden greenhouse, a demonstration greenhouse at the Hatchobaru power station and the Kokonoe Bio Center.

SENSUI ROSE GARDEN

Near Otake, the Rose Garden consist of 20 double glass greenhouses at 792 m^2 (8,525 ft^2) each. The greenhouses are terraced on a hill side in rows of five double houses as shown in Figure 1. A 100°C (121°F) geothermal well located 500 m (1,640ft) above the greenhouses can deliver 98°C (208°F) fluid at 7 tons/hr (31 gpm).

Figure 1. A row of five double greenhouses.

Perimeter mounted finned pipe, as shown in Figure 2, is used for the heating system in which 36 tons/hr (158 gpm) of fluid is circulated. Approximately 2.5 tons/hr (11 gpm) of geothermal make-up fluid is delivered to the heating system. Heat for the greenhouses is controlled by roof vents and thermal blankets which employ automatically at night. Conventional heat would cost about $260,000 to $280,000 per year. Geothermal fluids after heating the greenhouses supply a Japanese-style bathhouse (Figure 3), then disposed of to a nearby river.

The Rose Garden produces 1.8 million rose stocks per year selling at about $1.00/stock. They are trucked to Tokyo where they are sold at about $3.00/stock. The greenhouses were built in 1990 at a cost of about $8 million including the well, etc.

Figure 2. Roses and finned-pipe heating system.

Figure 3. Japanese-style bath using the effluent from the greenhouses.

HATCHOBARU GREENHOUSE

Near the cooling tower for the Hatchobaru power plant, a demonstration greenhouse has been built. The greenhouse was constructed of glass and is approximately 10 m (33 ft) by 20 m (66 ft) in size. The heating system utilizes 106°C (223°F) water from the condenser supplied to a forced-air heat exchanger. The heat exchanger is a cylindrical tank (1 m in diameter and 2 m high) with coiled 1 cm (0.4 in.) plastic tubing, and a fan is mounted on the top. The forced-air distribution system uses plastic polyethylene tubes (0.3 m or 1 ft diameter) placed under benches. Orchids are grown in the greenhouse.

Figure 4. Hatchobaru demonstration greenhouse.

KOKONOE BIO CENTER

The Bio Center is operated by the city of Kokonoe to raise bacteria-free plant starts sold to local farmers. Plants grown include gypsophila, eustoma, strawberry, and lavender flowers. Tips (from 0.1 to 0.2 mm) which are bacteria free are cut from new plants and transplanted to a sterile house where uniform heat is maintained. Geothermal heat keeps the air dry, therefore, limiting bacteria growth. Geothermal fluid at 60^{o}C (140^{o}F) is delivered from the Otake plant about 5 km (3 mi) and is also used for space heating and hot water in 150 homes in Kokonoe.

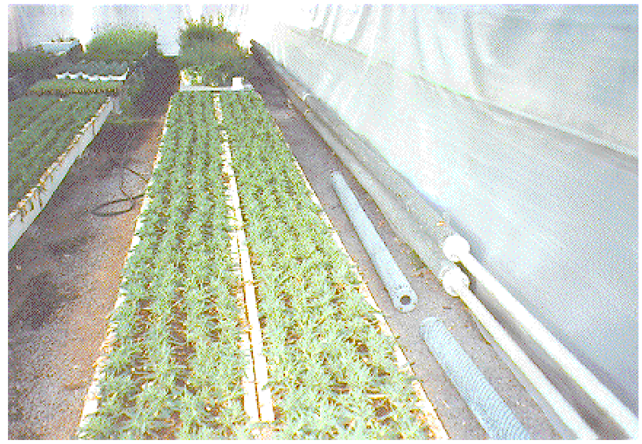

Figure 5. Bio Center greenhouse.

WHITE SULPHUR SPRINGS, WEST VIRGINIA

John W. Lund
Geo-Heat Center

A large, historic, health-oriented mineral springs resort, The Greenbrier, occupies 2,600 ha (6,500 acres) in an upland valley of the Allegheny Mountains near the West Virginia-Virginia border in the eastern U.S. Natural mineral water at 17°C (62.5°F) and with a high sulfate content is piped to individual soaking tubs of the mineral-bath wing, where it is heated by electricity to the desired temperature. Tubs are drained and filled after each use, so no chemical treatment is required. Water from a fresh-water spring is piped to an outdoor pool and the Grand Indoor Pool, where it is treated with chlorine and heated by steam. Thus, this mineral spring is not really geothermal, but has a two-century history of use by a spa resort (Loam and Gersh, 1992).

A chemical analysis of the spring gives a flow of 1.6 L/s (25 gpm) with sulphate 1400 mg/L, bicarbonate 210 mg/L, magnesium 130 mg/L, sodium 22 mg/L, silica 17 mg/L, chloride 17 mg/L, hydrogen sulfide 13 mg/L, potassium 1.2 mg/L and iron 1.1 mg/L (from *Springs of West Virginia*, West Virginia Geological and Economic Survey, 1986).

EARLY INDIAN LEGEND AND HISTORY

The Indian legend speaks of two young lovers who came to the valley to escape the notice of their elders. An enraged chief, catching them, shot two arrows, one killing the boy and the other barely missing the girl. Where the second arrow hit the ground, a sulphur spring appeared. The legend says that when the last drop of water is drunk from the spring, her lover will be restored to life (Conte, 1989).

The forests near the spring were originally inhabited by Shawnee Indians, and the small marsh around the spring was an ideal hunting spot due to the deposits of salt. Reports from early European settlers indicated that the Indians valued the curative powers of the water. In 1778, a Mrs. Anderson, hearing of benefits of the mineral water, was carried 25 km (15 miles) on a litter to the wilderness springs in order to attempt a cure for her chronic rheumatism (Conte, 1989). Following the Indian custom, a tree was felled and hollowed out as an improvised tub. It was then filled with spring water and heated with hot stones. Mrs. Anderson bathed in the water and drank from the spring. In a few weeks, the pain from the rheumatism receded and the news of her recovery spread rapidly to other settlers in the region. As a result, numerous log cabins were built around the spring in the next few years to house the crowd of visitors.

The earliest description of the spring was by Mr. Leven Gibson around 1787 (Conte, 1989):

> "The Spring, then in its natural state, emptied its water from between two flat rocks about twenty inches wide and about four inches apart, falling into a pool about three feet deep. I never saw the spring muddy--the changes of the weather had no effect in increasing or diminishing the quantity of water."

SETTLEMENT AND USE BY EUROPEANS PRIOR TO THE CIVIL WAR

Indians and the French and Indian War (1756-1763) prevented any serious settlement of the area until near the end of the 1700s. The land was originally surveyed around 1750 and then received the name Greenbrier region. In 1784, Michael Bowyer received clear title to 385 ha (950 acres) along Howard's Creek, a tributary of Greenbrier River, site of the present-day golf course. At the same time, Thomas Jefferson wrote of the spring in his "Notes on the State of Virginia (1784)", and noted of this spring and others in the vicinity that none had undergone careful chemical analysis and the medical benefits had not been studied enough to justify more than just an enumeration of the cures.

By the end of the 1700s, a primitive resort existed at "Bowyer's Sulphur Spring" consisting of log cabins around the spring. The access to the resort was assisted by the construction of the James River and Kanawha Turnpike through the mountains connecting Virginia with the Ohio River valley. This route, later named the Midland Trail, is present day U.S. 60, and portions of Interstate 64. Other springs were also being developed in the area: Sweet Springs, Warm Springs and Hot Springs.

The first half of the 1800s saw the development of Bowyer's wilderness resort into the south's grandest resort by his son-in-law and daughter, James Calwell and Polly Bowyer. The resort then took the name "White Sulphur Springs" a name derived from the white deposit left by the water on the surrounding rocks (Conte, 1989). A tavern had been constructed earlier by Michael Bowyer, and this was followed by a spring house to enclose the source of water. The spring house was a symbolic altar of health and a recognition of the importance of the spring in the commercial development of the resort. The top of the roof support a carved image of an Indian queen in costume carrying a bundle of arrows and a bowl--reinforcing the Indian legend (Figure 1). Meals were served in the tavern, reported to handle as many as 100 at a sitting. Parties and balls were also held in the tavern. To resort guests who sometimes complained about the rates, lodging, or food, James Calwell would reply somewhat like this, "You are paying me eight dollars a week for the use of the waters; I am giving you your food and lodging free" (Conte, 1989).

Figure 1. The earliest known photograph of the Spring House, taken in the 1850s, showing the original statue atop the dome (Courtesy of Mr. James S. Patton).

In the 1830s and 40s, the resort grew in guest capacity from about 200 to over 700, and the number of buildings was three times as many. The living quarters consisted of the older log cabins, ivy-covered white houses and magnificent private residences with tall white columns called the Colonnades. These rows of houses were built around a square facing the tavern and spring. The resort area grew from the original 385 ha (950 acres) to nearly 2,800 ha (7,000 acres), its size today. In 1857, a new hotel was begun, that became known throughout the nation as the Old White Hotel. It was large by the standards at that time, over 120 m (400 ft) across at the front with 228 guest rooms on the two upper floors, and a dining room, parlors, several reception rooms and a ballroom on the first. The dining room was the largest in the U.S., seating 1200 guest comfortably. By this time, the resort was handling crowds up to 1600 people.

Notable people who frequented the resort prior to the Civil War included Henry Clay, Dolly Madison, Daniel Webster, Davy Crockett, Francis Scott Key, John C. Calhoun, Presidents Martin Van Buren, John Tyler, Millard Fillmore, Frankling Pierce and James Buchanan, and Colonel Richard Singleton and Colonel Wade Hampton II, two of the wealthiest men in the south.

In 1838, Dr. John Jennings Moorman, began work at White Sulphur Springs, and transformed the practice of taking the waters from an act of faith into a systematic method of health care. Over the next 45 years, he became a nationally recognized authority on the uses and abuses of mineral water (Conte, 1989). His first published work in 1839, "A Directory for the Use of the White Sulphur Waters with Practical Remarks on the Medical Properties and Applicability to Particular Diseases" contained direction to avoid the misuse of sulphur water by using and drinking them in moderation. The most common error at the time was the belief among visitors that "they benefitted in proportion to the quantity which they drink" (Conte, 1989). As a general rule, he recommended four to eight glasses per day, working up to ten or twelve at most after two weeks, and believed that two weeks was the minimum period of time for the water to be effective, and its benefits began to appear only after three to six weeks (Figure 2).

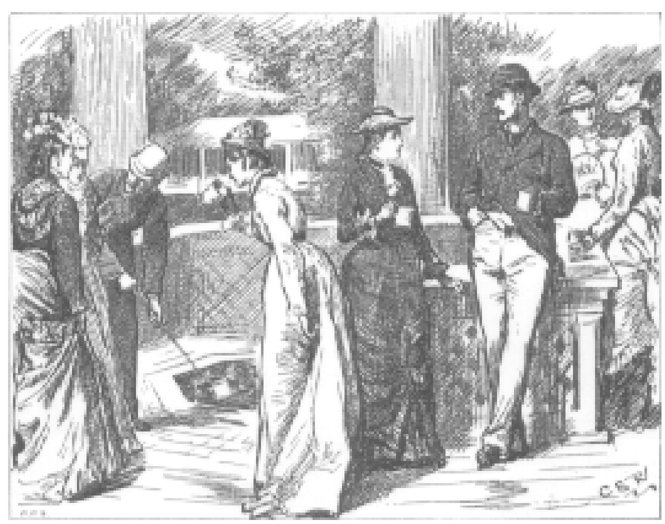

Figure 2. Visitors in the Spring House practicing one of the daily rituals of White Sulphur Springs.

Dr. Moorman felt the best use of the water was for the bowels, liver, kidneys and skin. He stressed that the water was not a panacea and therefore, prescribed it for only a limited range of diseases, including dyspepsia (derangement of the functions of the organs of digestion--his definition), chronic rheumatism, neuralgia, jaundice, scurvy and a few others. He found it of limited use, along with other treatments, for addiction to alcohol and opium. The sulphur water should not be used, he wrote, for acute diseases, cancerous infection, or heart problems. He did acknowledge that a cure, or at least relief, derived from a combination of drinking the water (he thought that bathing in the water was useful only after drinking the water for a period of time) plus attention to a moderate diet, sensible clothing, daily exercise, abstaining from liquor and breathing the clean mountain air. Others tried to counter his skepticism with extravagant claims that a veritable fountain of youth poured forth from the spring. One visitor wrote, "It cures ugliness itself, being a kind of elixir of external youth," and furthermore, it "restores physicians to health, causes sailors to forget, and lawyers to confess the truth."

Dr. Moorman was also involved in recommending the sale of the spring water in bottles and barrels for home use, starting in the early 1840s. The marketing effort was so successful that in later years this branch of the resort's operation became a major source of income. However, there was a controversy concerning whether the water's curative powers lay in its gaseous contents or in its solid salt contents. The contention from rival spring bottlers was that the gases escaped before the time they were consumed. Dr. Moorman felt it made no difference, and the resort continued to bottle the water. It was billed as "America's Favorite Morning Laxative" and the sales continued as late as 1942, when the bottling equipment was dismantled (Figure 3).

Figure 3. 1920s literature promoting the mineral waters.

THE CIVIL WAR YEARS

The state of West Virginia was created from the western part of Virginia by President Lincoln's proclamation in 1863. White Sulphur Springs was included in this new state, just over the Virginia boundary. Both Union and Confederate troops stayed at the resort and several battles were fought nearby. The resort was also used as a hospital, especially after "The Battle for the Law Brooks" in 1853 with Colonel George S. Patton, grandfather of the World War II general of the same name, commanding the Confederate troops to protect the Virginia State Law Library in Lewisburg. There is a mass grave of 16 unknown Confederate soldiers located on the Greenbrier property. The resort was saved from burning by the Union Troops through the efforts of Captain H. A. Dupont in 1864. After the war, General Robert E. Lee and other military leaders spent time at the resort.

THE GOLDEN AGE OF RESORT HOTELS

Social activity at the resort quickly returned after the "War Between the States" (Figure 4); however, its financial situation was not the best. Much needed repairs to the property had to be delayed until debts were settled. One bright event was the arrival of the first train in 1869, providing passenger service on the Chesapeake and Ohio Railway. This guaranteed the resort's survival, especially since it was the only resort among the Springs of Virginia that could boast of service directly to its main gate. The railroad made the act of traveling pleasurable, as travelers from Washington, D.C., for example, reached the resort in 15 hours rather than the four or five days necessary in the past. Not only were the resorts

Figure 4. Brochure cover after the Civil War showing the resort's location in the new state of West Virginia.

Figure 5. An 1883 poster showing the resort's location on the C&O Railway.

made accessible by the railroad to wealthy patrons, but to more middle-class travelers as well (Figure 5). More were traveling; but, a trend that developed throughout the U.S. brought about by this ease of travel, their stays were for shorter periods.

The resort then became a grand resort hotel on par with the most elaborate competitors spring up across the U.S. (Figure 6). White Sulphur Springs resort had two special characteristics that the newer resorts did not have: a deep-rooted historical environment, and perhaps, the more crucial feature, scores of classic Southern Belles. A popular saying at the time (1889) was: "The Lord made the White Sulphur Springs and then the southern girl, and rested satisfied with his work."

Unfortunately, all of these advantages were not enough. No owner during the nineteenth century were ever able to make the resort financially solvent, at least for any length of time. Thus, in 1910, the resort was purchased by the Chesapeake and Ohio Railway and then immediately turned its attention and considerable funds towards restoring the declining resort. Tennis courts and a golf course were laid out at this time. A new Bath Wing was added, and to insure that it stayed the nation's best health resort, a team of medical experts traveled to many of the famous spas of Europe to insure that the therapy and equipment offered matched the finest in the world. The company brochures proclaimed that the resort was "A European Cure in America." This later had special meaning, as it was difficult to travel to Europe for "the cure" during World War I.

The Bath Wing featured a huge pool on the first floor, "which might have been the pride of Rome" as described by one writer (Figure 7). It measured 30 m (100 ft) by 13 m (42 ft), and at the time was one of the largest in the world. It was housed under a glass dome and encircled by broad walks. On the second and third floors were hydrotherapy services including mud baths using mud obtain from the bed of nearby springs, used in the treatment of gout, rheumatism and neuritises; the Vichy Bath, a massage under a spray of water at moderated temperature; and an Inhalation Room with "Apparatus for the inhalation of the volatile properties of the mineral water" useful for treating the nose, throat, lungs and certain types of asthma (Conte, 1989).

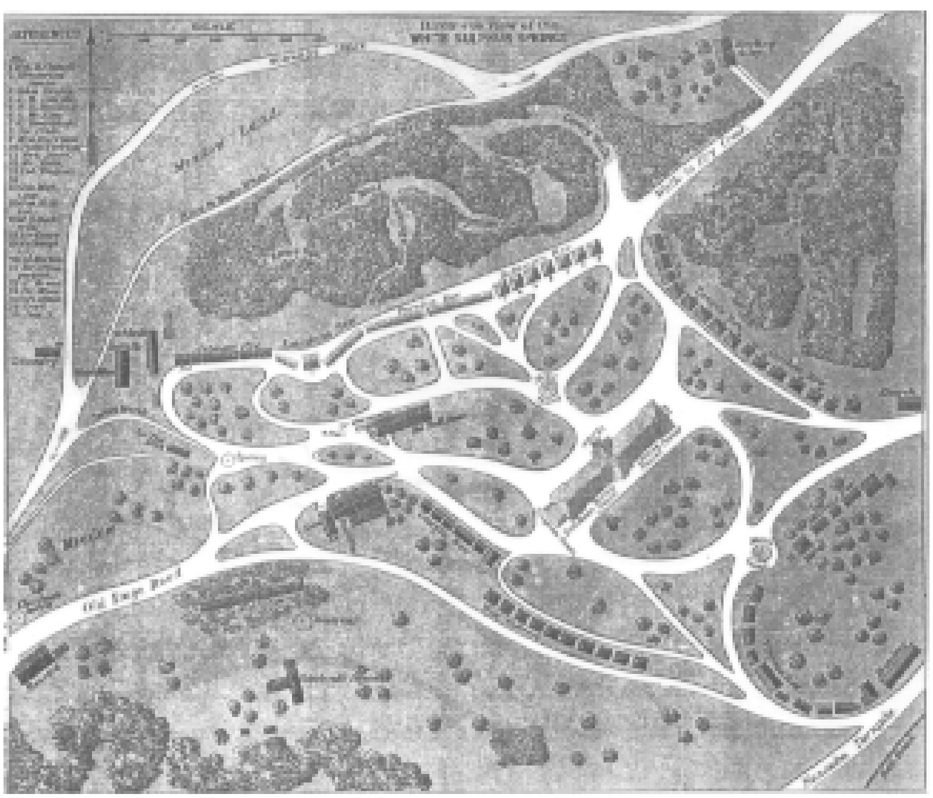

Figure 6. Map from 1880 showing the layout of the resort's grounds.

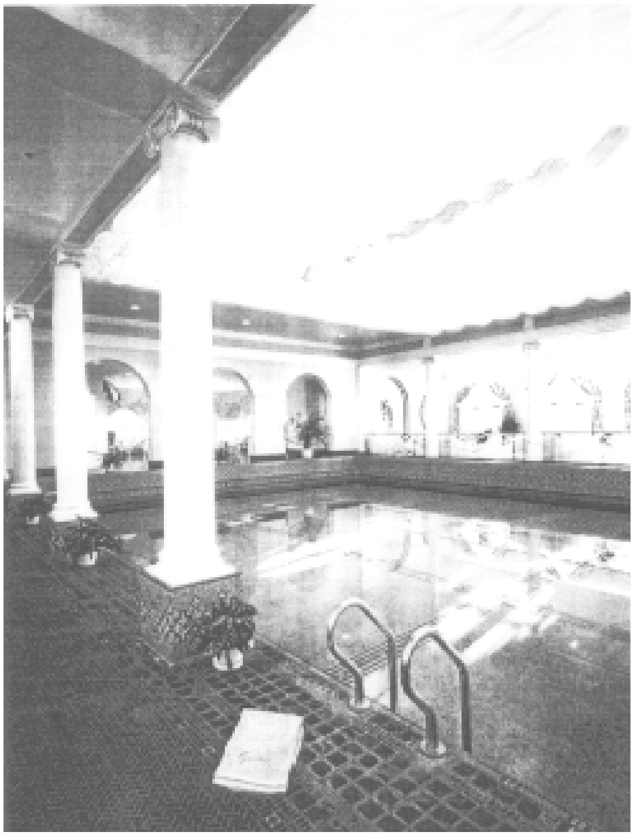

Figure 7. The indoor pool at the Greenbrier opened in 1912.

The other major structure completed about the same time (1913) was The Greenbrier Hotel. It was six stories high, and had 250 rooms, with a ballroom, billiard room, card room, dining room and shops. It was fireproof stone and concrete, unlike its wooden predecessor Old White, and built in Georgian architectural style. It forms the central section of today's building. The Old White was torn down in 1922 when it couldn't pass the West Virginia fire inspection code. The Greenbrier Hotel was rebuilt and doubled in size to 580 rooms in 1930. An airport was also opened around this time. Tennis and golf became two major attractions for the resort, with Sam Snead as one of the young golf pros.

Notable personalities who stayed at the resort prior to World War II included: Presidents William Howard Taft and Woodrow Wilson, Mr. and Mrs. Joseph P. Kennedy, Mr. and Mrs. Cornelius Vanderbilt, Eleanor Roosevelt, Babe Ruth, Mary Pickford, Booth Tarkington, Bing Crosby, Ethel Barrymore, Generals John J. Pershing and Billy Mitchell, and the Prince of Wales (later King Edward VIII of England). The Duke and Duchess of Windsor returned to the Greenbrier after the war as private citizens.

WORLD WAR II

In December 1941, The Greenbrier became the temporary house for diplomats from the Axis powers until exchanges for American diplomats held overseas could be officially negotiated. The entire resort then housed representatives from Germany, Hungary, Italy, Bulgaria and later included Japanese diplomats. They were all finally exchanged by July 1942. The resort then reopened for a short six-week period to the public, before being "drafted" into wartime duty again as a hospital for the U.S. Army. The Greenbrier was condemned under the War Powers Act, and the C&O Railway was paid $3.3 million for a resort that was estimated to be worth $5.4 million. It was converted into a 2000-bed military hospital, with most of the bulk of the elaborate interior furnishings auctioned off. The new facility was named Ashford General Hospital, after the Army doctor who did much of the research on epidemic diseases in Puerto Rico. After investing nearly $2 million in the transformation, the hospital was formally dedicated in October 1943. The press nicknamed it "The Shangri-La for Wounded Soldiers." Prisoners of war from Germany and Italy were used for workers in the kitchen, laundry and on the grounds. A number of American generals, such as Eisenhower, Bradley, Marshall, Clark, Ridgeway and Wainwright were visitors or patients here.

POST WAR YEARS

The hospital was closed in 1945 and then sold back to the C&O Railway for about the same price as it was condemned for in 1942. After investing over $12 million into renovating the property under the decorating skills of Dorothy Draper, it was opened to the public again in 1948. It was recognized at this time that many business leaders aged prematurely largely because they neglected to maintain their health; thus, the Greenbrier Clinic was created in 1947 where executives would attend to their health through preventative medicine.

Many important conferences and meetings were held at The Greenbrier in the post war period. Notable ones were The United Mine Workers of America headed by John L. Lewis, a secret meeting of the Secretaries of the Army, Navy and Air Force with the Joint Chiefs of Staff, the Annual Governor's Conference in 1950, and the North American Summit Conference hosted by President Eisenhower in 1956. In 1952, work was started on the new West Wing so as to better accommodate these conferences. A secret bomb shelter was constructed under the building at the same time, designated for occupancy by members of Congress in the event of an emergency during the "Cold War." In 1974, Colonial Hall was also added with a spacious meeting room and a dining room capable of seating 1,200 guests. In the 1950s and 60s, The Greenbrier advertized itself as "America's Informal Business Capitol" and in the 1980s one writer described the resort as an "alternate Camp David for America's permanent government."

Famous guests who stayed at The Greenbrier after the war included all the U.S. Presidents from Eisenhower through Clinton, Prince Rainier and Princess Grace of Monaco, Debbie Reynolds and Eddie Fisher on their honeymoon in 1955, and Indian Prime Minister Nehru.

In 1956, The Greenbrier's engineers installed an outdoor swimming pool, a task that proved extremely delicate because the pool was designed to sit directly over a number of underground tributaries feeding the ancient spring of sulphur water. The other major event relating to the mineral waters was the opening of the new Mineral Bath and Spa Building in 1987. This is a luxurious facility for the oldest of rituals, "taking of the waters."

PRESENT TIME

Today, The Greenbrier is a major social and health resort, with golf and tennis as major attractions. It offers the same constant appeal: a splendid setting for the pursuit of health, pleasure and agreeable society.

According to their spa brochure: "The Greenbrier offers a variety of a la carte services to help guests attain total health and fitness, beauty and grooming. In addition to the centuries-old rejuvenating treatments..., many inspired by European spas, we offer innovative exercise programs tailored to your personalized needs. The Greenbrier Spa features an indoor pool with heated wet-deck... Our bath facilities include soak tubs, individual whirlpool baths, swiss shower, scotch spray, steam, sauna and therapy rooms for massage... Our natural mineral waters are freshly drawn in facilities carefully cleansed and sterilized between treatments, with temperature fully regulated to guest preference."

The National Park Service designated The Greenbrier a National Historic Landmark in 1990, in recognition not only the resort's place in history, but its preservation of the past.

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HOT SPRINGS, VIRGINIA

John W. Lund
Geo-Heat Center

INTRODUCTION

Three major springs are located in the Warm Springs Valley of the Allegheny Mountains in western Virginia along US route 220--the Warm, Hot and Healing--all now owned by Virginia Hot Springs, Inc. The Homestead, a large and historic luxurious resort, is located at Hot Springs. The odorless mineral water used at The Homestead spa flows from several springs at temperatures ranging from 39ºC to 41ºC (102 to 106ºF) (Loam and Gersh, 1992). It is piped to individual, one-person bathtubs in separate men's and women's bathhouses, where it is mixed to provide an ideal temperature of 40ºC (104ºF). Tubs are drained and refilled after each use so that no chemical treatment is necessary. Mineral water from the same springs is used in an indoor swimming pool maintained at 29ºC (84ºF), and an outdoor swimming pool maintained at 22ºC (72ºF).

Eight kilometers (5 miles) away to the northeast, but still within the 6,000-ha (15,000-acre) Homestead property, are the Warm Springs, which flow at 36ºC (96ºF). The rate of discharge is so great, 63 L/s (1000 gpm) (Muffler, 1979) that the two large Warm Springs pools, in separate men's and women's buildings, maintain the temperature on a flow-through basis requiring no chemical treatment. The men's pool was designed by Thomas Jefferson and opened in 1761; the ladies' pool was opened in 1836. The adjacent "drinking spring" and the two covered pools have been preserved in their original condition.

The approximate partial analysis of the Warm Springs pools are as follows (Source: undated brochure from The Homestead): bicarbonate 194 mg/L, sulphate 160 mg/L, iron 120 mg/L, sodium 5.4 mg/L, chloride 1.5 mg/L and nitrate 0.10 mg/L. Total dissolved solids are reported as 388 mg/L (calculated); however, Muffler (1979) reports 525 mg/L and 586 mg/L for Hot Springs.

Healing Springs located approximately 8 kilometers (5 miles) to the southwest of Hot Springs is reported at 30ºC (86ºF) with total dissolved solids of 596 mg/L at less than 1 L/s (15 gpm) flow (Muffler, 1979).

The facilities at The Homestead include 700 bedrooms, a conference center, restaurants, shops and tennis courts. Skiing and ice skating are available in the winter. It is the only Virginia spa still in operation as a public resort.

EARLY HISTORY

The three springs have been visited for hundreds of years, with the discovery associated with an Indian brave in the 1600s (Cohen, 1981). By the middle of the 1700s, a few white settlers had found their way into the valley, and George Washington visited the area in 1755 while constructing forts for protection against the Indians. The first recorded inn was built by Thomas Bullitt in 1766 to take care of guests who were looking for a cure from the thermal waters.

Hot Springs became one of the dominant resorts of Virginia after Thomas Goode, a physician acquired it in 1832. He was a salesman who exaggerated the benefits of the mineral waters, claiming that it would cure most diseases or relieve the symptoms (Figure 1). He expanded the resort and opened a hotel called The Homestead in 1846--the site of the present day hotel (Figure 2). He also built cabins and bathhouses that attracted many notable people. The resort became one of "the" spas on the summer circuit for the south (Cohen, 1981).

Figure 1. Early poster advertising the Hot Springs.

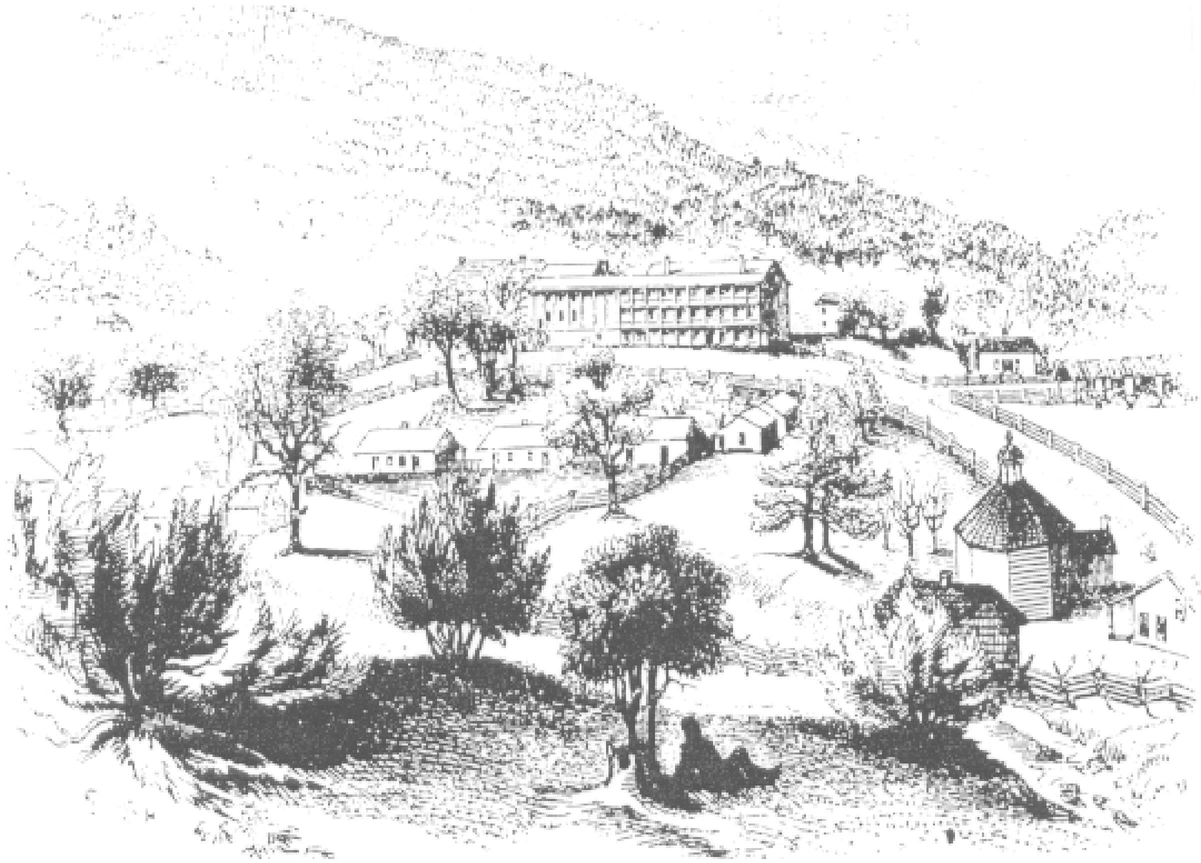

Figure 2. The Hot Springs resort as drawn by Porte Crayon in 1857. The large hotel is The Homestead, built by Thomas Goode in 1846.

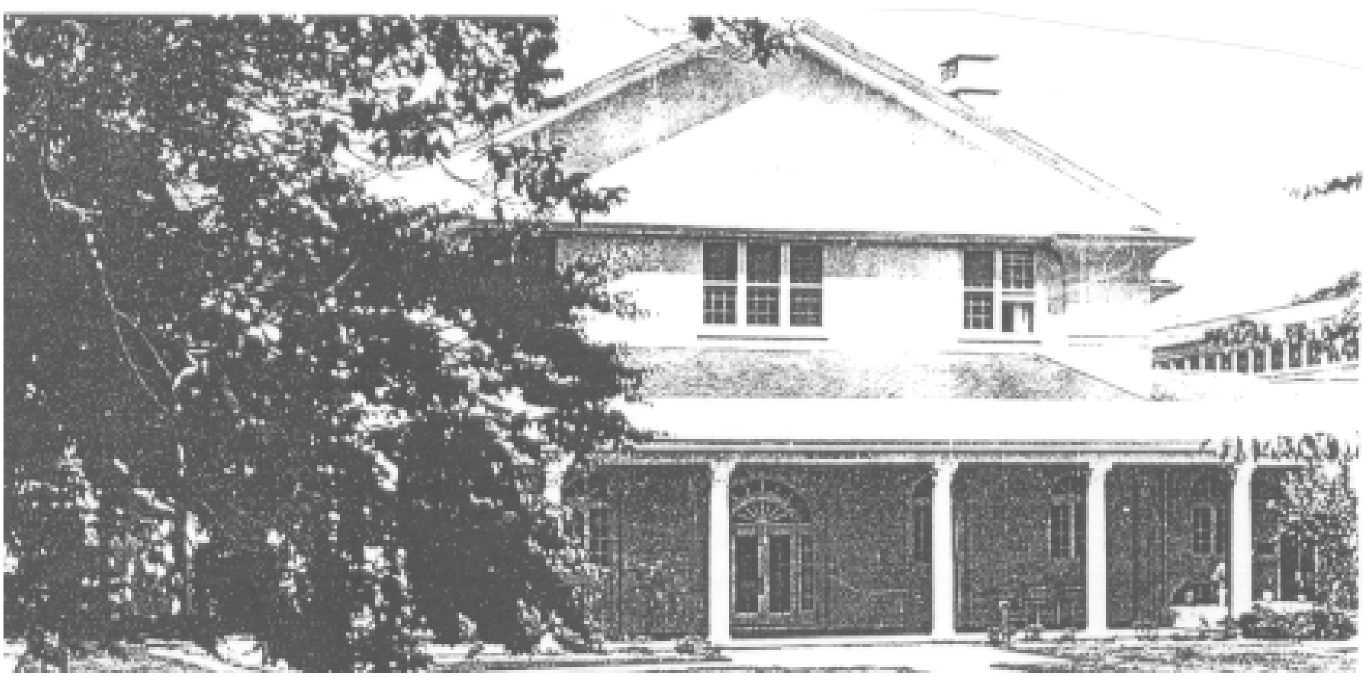

Figure 3. The spa at The Homestead, built in 1892 and still offering full-time health treatment for the guests. It has been extensively remodeled.

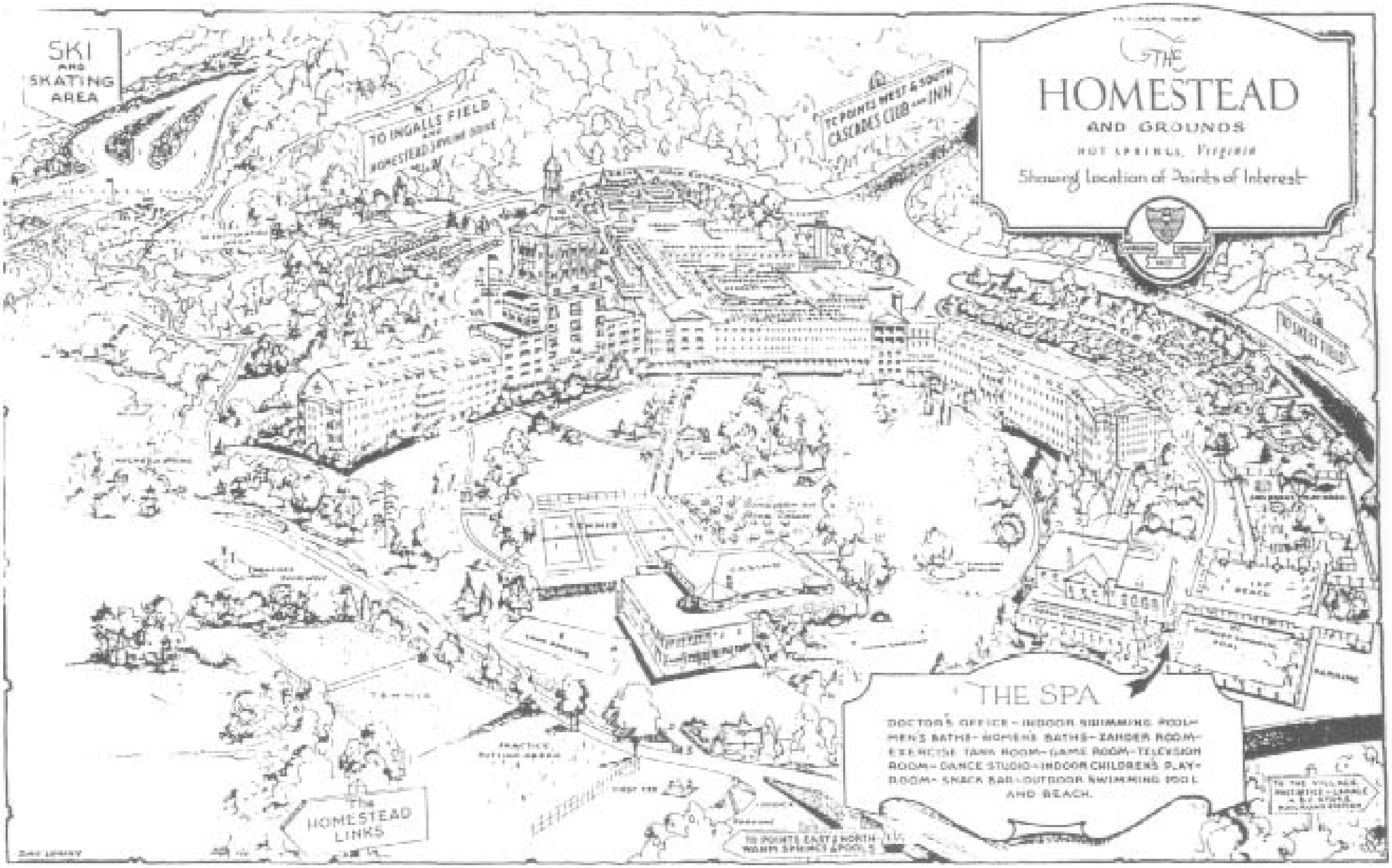

Figure 4. Pictorial map of The Homestead.

THE CIVIL WAR YEARS AND AFTER

Several battles were fought nearby during "The War Between the States" and the hotel was used as a Confederate hospital. The hotel survived the war, but was in a state of disrepair.

The modern development of the resort began in 1890 when the South-Improvement Company bought all three spas in the Warm Springs Valley--amounting to about 1,900 ha (4,700 acres). This company was part of the same syndicate that owned the Chesapeake and Ohio Railroad, also the owner and developer of The Greenbrier across the border in West Virginia. In 1892, a railroad spur was built to the resort, and the hotel was rebuilt and refurbished. The Virginia Hotel was also built as part of the railroad station while The Homestead was being repaired. Unfortunately, The Virginia was built in the low part of the valley with no view and polluted by the smoke from locomotives; thus, it was used little after The Homestead was finished, and is now a dormitory for workers at the resort.

Also in 1892, the present bathhouse was completed (Figure 3), modeled after the European spas, featured two main kinds of treatment--hot tubs for soaking and hot showers or "spouts" (Cohen, 1981).

In 1901, a fire reduced The Homestead and several outbuildings to ashes. It was rebuilt and ready for occupancy by 1904. The east wing was completed in 1914. It was then one of the largest hotels in the south. More rooms were added after World Wart I, including an imposing tower that now dominates the building.

WORLD WAR II AND AFTER

Like The Greenbrier, The Homestead became a home for Japanese diplomates (1941-42), who were interned until negotiations could be completed to exchange them for American diplomates. The internment program proved to be a financial disaster for the spa. The Army and Navy both considered the resort as a possible hospital; but, this option did not develop.

After the war, the resort began housing guest again. In 1948, the railroad was bought out and the holdings in the valley reached over 6,800 ha (17,000 acres), including three health spas. In 1959, snow machines brought skiing to the area to help the winter business. In 1973, the south wing with 190 guest rooms and a conference center was added.

THE PRESENT

Today Virginia Hot Springs, of which The Homestead is the main center, has over 700 guest rooms with a capacity of 1,100 people and employs up to 1,000 people (Figure 4). The Spa provides hydrotherapy (sauna, steam, mineral baths and spout baths), aromatherary (mineral baths, loofah scrub and herbal wraps), massage therapy (traditional Swedish and aromatherapy massages), and fitness activities. Swimming is provided for by an indoor pool and two outdoor pools.

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THE NEVADA GEOTHERMAL INDUSTRY - 1996

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INTRODUCTION

Nevada ranks second in the United States for overall geothermal utilization and number one on a per capita basis (Table 1). Nevada's geothermal power plants generate approximately 210 megawatts (MWe) of electricity (gross), enough for about 200,000 households. Modern development began during the 1980s; but, geothermal utilization can be traced from prehistoric applications by indigenous Native Americans to modern uses. In July 1984, the first electricity generated from a Nevada geothermal resource occurred at Wabuska, in Lyon County. The binary electric power plant yielded an output of 600 kW, and the electricity was purchased by Sierra Pacific Power Company. Today, Nevada's geothermal resources support twelve electric power plants at ten sites, representing a total investment of approximately $450,000,000. Several large-scale direct-use projects have also provided significant economic and environmental benefits. Conservative estimates suggest that the 210 MWe presently produced in Nevada could easily be doubled or tripled, from identified existing geothermal resources if sufficient market demand exists.

Table 1. States That Produce Geothermal Electricity

State	Population	Installed Geothermal	Watts/Person
Nevada	1,200,000	210 MWe	173
California	30,000,000	2,500 MWe	83
Hawaii	1,120,000	25 MWe	22
Utah	1,730,000	33 MWe	5

Population data from 1990 Census. Electric power data (Hoops, 1994)

Geothermal resource development in Nevada accelerated in the 1980s for several reasons: the finite-nature and volatile costs of conventional fossil fuels, economic and institutional incentives, the environmental impacts of combustion, and technological advances within the geothermal industry. The key to sustained development is to balance long-term energy demands and costs, with long-term environmental and economic benefits. This report examines the historical development, describes recent events, and suggests several possible futures for geothermal energy in Nevada.

HISTORY

Commercial-scale geothermal development began in the United States in 1960 with the start-up of the first power plant at the Geysers field in northern California. Subsequent development continued at a moderate pace until the energy crisis and Arab Oil Embargo in 1974. Geothermal energy resources were identified as a way to preserve indigenous petroleum resources and ensure future energy supplies. Major project development accelerated in the western United States and can be traced to post-crisis development incentives including government sponsored research programs, changes in the laws governing geothermal leases on public lands, economic incentives by electrical utilities, and advances in energy conversion equipment.

Several technologies have been developed to extract heat efficiently from hot water resources including single flash, dual flash and binary-cycle systems (Table 2). Most of the conventional flash plants operate at higher temperatures and use a portion of the geothermal fluid in the cooling and condensation cycle, which conserves potable water supplies.

ELECTRIC POWER GENERATION

Low- to moderate-temperature geothermal resources are becoming increasingly more attractive as a prime source for the generation of electricity for several reasons. Geothermal technology has advanced rapidly in the areas of binary power systems, reliability, and dry cooling systems. Binary power plants generally tap lower temperature resources than flash plants and utilize a second working fluid, in addition to the geothermal fluid, to produce electricity. Typical installations operate at temperatures between 120°C and 180°C, and use either pentane or iso-pentane as a secondary working fluid.

DIRECT UTILIZATION

As the name implies, direct-use application employ geothermal heat directly, with no conversion to electric power. Nevada ranks number one for direct utilization of geothermal energy. Mining, aquaculture and agriculture benefit from the direct utilization of geothermal resources. The Elko County School District and the Elko Heat Company operate geothermal district space heating systems that provide hot water to municipal, residential and commercial establishments. The Elko Heat Company, one of Nevada's largest geothermal district heating system, has provided service to Elko since

Table 2. Nevada's Geothermal Power Plants

Plant Name Owner/Operator	County	Year On-Line	Installed Capacity (MWe)	Estimated Cost of Construction ($000)	System Type
Wabuska - Tad's	Lyon	1984, 87*	1.2	2,000	Binary Cycle
Desert Peak - California Energy	Churchill	1985	10.0	18,000	Single Flash
Beowawe - Oxbow	Lander	1985	16.3	30,000	Dual Flash
Steamboat - Far West	Washoe	1986, 88, 92	47.0	70,000	Binary Cycle
Soda Lake - OESI	Churchill	1987, 91	23.0	45,000	Binary Cycle
Empire - OESI	Washoe	1987	4.8	12,000	Binary Cycle
Steamboat - Caithness	Washoe	1988	13.5	30,000	Single Flash
Dixie Valley - Oxbow	Churchill	1988	62.0	140,000	Dual Flash
Stillwater - OESI	Churchill	1989	13.0	37,000	Binary Cycle
Brady's - Brady Power Partners/Oxbow	Churchill	1992	20.0	65,000	Single Flash

* Note: Multiple years indicate power plant additions or modifications.

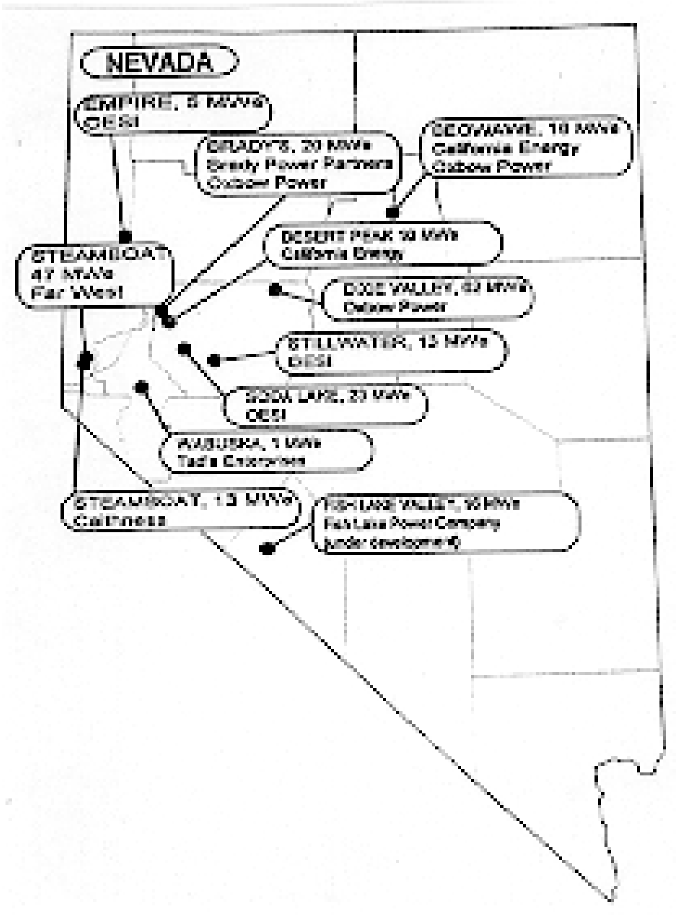

Figure 1. Location of Nevada's geothermal power plants showing production in megawatts and the name of the plant operator.

1982. Approximately 250 homes and businesses in Reno use geothermal energy for space heating. The Warren Estates subdivision supplies hot water to more than 100 private homes from a single geothermal well. Two food dehydration plants now produce dried garlic and onion using geothermal heat as the heat energy source. Geothermal fluids are used in gold mines to accelerate cyanide heap leaching and extent the leaching season. Energy tax credits for geothermal projects provided a 40% "write off" on capital investments placed online before June 1985. This single item was responsible for 70 to 80% of all residential geothermal installations in Nevada.

REGULATORY ASPECTS

Development of geothermal resources in Nevada is regulated by a combination of federal and state agencies. The principal federal agency is the Bureau of Land Management (BLM). The BLM regulates drilling and resource development. The principal state agencies include the Division of Minerals (drilling permits), Division of Environmental Protection (injection permits), Division of Water Resources (drilling and water consumption), and the Public Service Commission of Nevada (economics and power purchase agreements). In Washoe County, a permit is required from the Air Quality Management Division of the Washoe County Health Department.

ECONOMICS

Historically, renewable energy sources have been perceived as being non-competitive with fossil fuels. Many of the power plants in Nevada receive higher-than avoided cost payments for electric power. These contracts were developed to offset some of the initial capital expenses associated with well drilling and equipment purchases. Two power plants in Nevada (Steamboat Units 2 & 3) were constructed as a result of winning competitive bids with conventional power plants because of higher fuel prices in 1989. Electric power generated from geothermal resources is purchased by two utility companies: Sierra Pacific Power Company of Reno, Nevada and Southern California Edison Company.

Many utility companies, including Sierra Pacific Power Company, recognize the value of including renewables in their resource mix. Geothermal energy, for example, is included in many utility energy portfolios along with fossil-fuels in California, Nevada, Hawaii and Utah. Nevada benefits from the use of renewable resources, especially geothermal, as evidenced by the various revenues earned from geothermal operations. The Nevada Department of Taxation, Division of Assessment Standards, reports that net proceeds tax, property tax and county tax payables have increased for geothermal plants throughout the state, especially in rural areas such as Churchill County (Table 3).

Leasing and Royalties

Leaseholds in the United States have stabilized since 1991. Nevada leads the nation in geothermal leaseholds with approximately 29,000 acres. California and Utah follow, and New Mexico, which does not produce electricity, has nearly 5,000 acres of geothermal leases. Hawaii's geothermal resources are all produced on fee land.

The Bureau of Land Management collects royalties on geothermal energy produced on federal leases both on electricity and on heat. Land leased within a KGRA or on the basis of competitive bids is charged $2.00/acre; all other land is charged $1.00/acre. The royalty rate is ten percent of gross proceeds, minus transmission and generation deductions. The result is a royalty rate equal to 3.5 to 4 percent of the gross proceeds. This number is significantly lower than the 10 to 15 percent originally proposed in the Geothermal Steam Act of 1971.

In 1992, Nevada produced 1,219,700 megawatt hours (MWh) of geothermal electricity and a sales volume of about $85 million dollars, based on a net production of 1,034,800 MWh. In addition, federal geothermal leases on 348,000 acres generated rent and royalty fees of $2,926,200, according to Bureau of Land Management reports (Hoops, 1994). In 1994, geothermal electric power on federal land was 1,033,665 MWh for a total sales volume of 98,563,783. A total of $4,476,624 dollars were collected. Figures are incomplete for 1995; but, through September, royalties collected equal $3.2 million. One-half of these revenues are returned to Nevada's general fund (Hoops, 1995).

Table 3. Revenue and Taxes Received from Geothermal Operations in Nevada

Year	Actual Gross Proceeds	Actual Net Proceeds	Actual County Tax	Property Assessed Value	Property Taxes Due
1989	$58,876,628	$18,114,494	$345,516	$63,134,750	$1,342,691
1990	$68,003,694	$28,133,212	$631,253	$53,105,610	$1,258,415
1991	$74,253,212	$29,570,221	$694,578	$57,328,100	$1,400,386
1992	$82,814,226	$35,602,681	$864,815	$60,957,720	$1,990,902
1993	$102,164,450	$37,432,245	$827,645	$68,211,000	$1,656,424

Data Source: Nevada Department of Taxation (NDT, 1994).

ENVIRONMENTAL

Based on 210 MWe produced by Nevada's geothermal power plants, the following volumes of fossil fuels were conserved: 821,100 tons of coal, or 3,066,000 barrels of oil, or 18,396,000 million cubic feet of natural gas (Goddard, et al., 1989). Electric power generation and the preservation of the environment are of tremendous importance to Nevada's utility industry. Geothermal power plants, for example, have incorporated several award-winning technologies. California Energy Co., Ormat Energy Systems, Inc. (OESI), and Pacific Gas & Electric Co. have received environmental awards for their role in reducing greenhouse gases and ozone depleting chemicals. The awards recognize the reduction in pollutants achieved by modifications to the power generation process. Sierra Pacific was recognized in the June 1994 issue of Money Magazine as an environmental leader among the top utilities from around the country who are "outstanding in pollution control, hazardous waste reduction, and energy conservation." More recently, Sierra Pacific was one of six utilities to receive acid rain bonus allowances from the U.S. Environmental Protection Agency for undertaking energy efficiency and renewable energy measures. Some of this recognition can be attributed directly to the incorporation of geothermal energy into the utility resource plan.

CONCLUSIONS

It has been projected that geothermal capacity and generation in the USA could realistically increase from 2,590 MWe in 1990 to 23,400 MWe in the year 2030 (EIA, 1991). These forecast amounts were based on expected expansions from fields developed in California, Nevada and Utah, as well as the development of new fields in Oregon, Hawaii and New Mexico. However, these assessments require that renewable energies receive a share of the power market along with existing electricity generation technologies.

Geothermal development has accelerated in the last fifteen years largely as a result of government supported financial incentives that can be traced to the Arab Oil Embargo. The relatively benign nature of the resource has also contributed to development of both electric power and direct use projects. By the year 2010, the electric capacity for northern Nevada is projected to be about 2000 MWe. An achievable goal is to produce an additional 200 MWe of geothermal power over the next 15 years, which requires 20% of the resource mix is derived from renewable energy. Given the present avoided costs for electric power, the restructuring of the entire electric power industry, the present abundance of natural gas and hydo-power, the lack of a clear energy policy, and the equivocal arguments associated with global warming and greenhouse gases, the future of Nevada's geothermal resources is uncertain.

Since the use of additional renewable resources enhances our national energy security, reduces regional air pollution, and provides increased visibility, these actions should be encouraged on the federal level with a combination of tax credits and financial incentives. When all of the environmental and economic aspects are factored, geothermal energy is competitively priced, produces minimal or negligible atmospheric emission, can be developed as smaller, economically sized plants to closely match load growth, provides long-term, high-capacity factor operation, and represents fuel diversification to assure long-term, reliable electric power.

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GEOTHERMAL PIPELINE

Progress and Development Update
From the Geothermal Progress Monitor

CALIFORNIA

Glass Mountain Geothermal Power Project to Move Forward

The Bonneville Power Administration has reached an agreement with two power companies to proceed with an environmental analysis of the Glass Mountain geothermal power project on the Klamath National Forest.

The Bureau of Land Management will take the lead in drafting an environmental impact statement (EIS), working in cooperation with BPA, the Forest Service and Siskiyou County. Agencies involved in the process met the week of April 25th.

The 49-megawatt project, expected to be completed in three years, is proposed by Calpine Corp., based in San Jose, California and Trans-Pacific Geothermal Corp., based in Oakland.

The project is proposed for construction along the border of the Klamath and Modoc national forests, near Medicine Lake about 50 miles south of Klamath Falls.

A test well drilled last year to a depth of about 500 feet revealed the geothermal aquifer is capable of power production, said Maurice Richard, program manager for Calpine.

"We're satisfied with the results that we have, and therefore, we have confidence to proceed with the expenditure required to proceed with an EIS," Richard said.

Water temperatures of at least 450^{o}F are required to generate power, Richard said. Additional holes are expected to be drilled over the next two years, he added.

The environmental impact statement will cover construction and operation of the plant, a 24-mile transmission line and power purchase agreements. The EIS is expected to be completed by the fall of 1997.

BPA said it is pursuing new sources of "renewable" power despite their relatively high cost, and even though there is currently a surplus of electricity in the northwest.

"BPA's approach to developing and marketing green power products reflects the (U.S. Energy) department's desire to encourage long-term investments that will benefit future generations in the region," said Charles Curtis, deputy secretary of Energy Department.

BPA officials said the Glass Mountain project is located in an area capable of producing 500 megawatts of power, and is one of the world's largest untapped geothermal resources.

Katherine Potter, spokeswoman for Calpine, said construction would create about 200 temporary jobs, and 15 - 20 permanent jobs. There is no firm estimate of construction costs, she said.

Glass Mountain is one of several renewable energy projects proposed in the northwest. The Newberry Geothermal Project has been issued a permit for construction on the Bend-based Deschutes National Forest.

Other projects include wind power facilities in Wyoming and Washington. *(Herald & News,* April 19, 1996)

OREGON

Alvord Geothermal Power Project Put On Hold

A California energy company has put the brakes on plans for a controversial geothermal power plant in the remote Alvord Desert in southeastern Oregon.

Anadarko Petroleum Corp. has asked M. H. A. Associates of Sacramento, California to suspend work on an environmental impact statement on the plant, said Cody Hansen, Burns district manager for the U.S. Bureau of Land Management.

The site is on BLM land about a mile from Borax Lake, the largest geothermal lake in Oregon. The lake is just north of the high desert settlement of Fields.

Hansen said the project has been stalled because Anadarko and Portland General Electric were unable to reach a power purchase agreement consistent with an April 1995 memo of understanding between the two.

PGE, initially had agreed to purchase 22.9 megawatts of electric power from the proposed plant.

Anadarko wants to review the project plans with BLM officials in July, said Hansen. But he said the federal agency wouldn't be able to participate in serious planning to resurrect the project until October 1996, the start of BLM's 1997 fiscal year, even if Anadarko decides to proceed with it again.

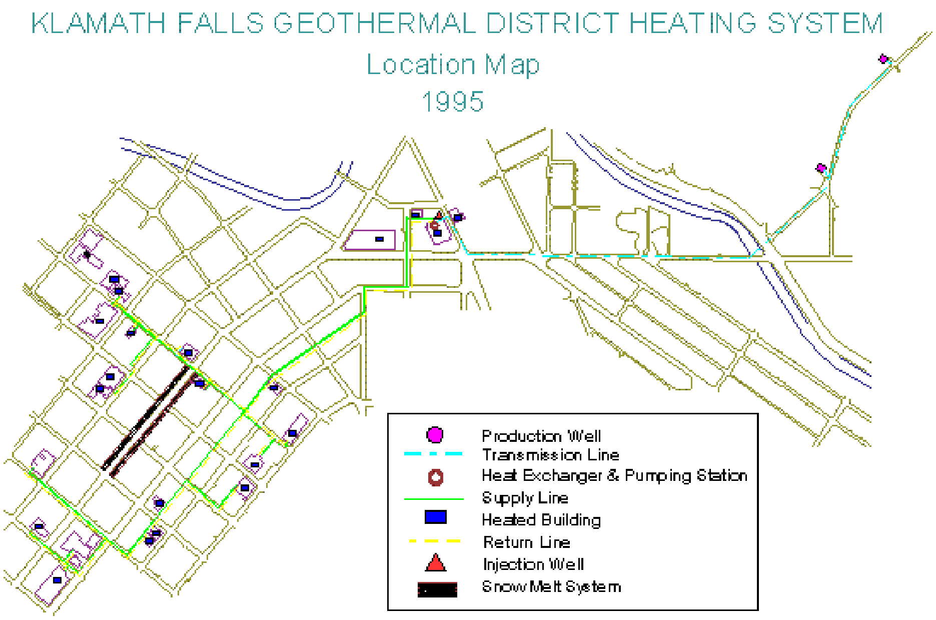
The proposal has attracted state-wide interest over the past few years because of environmental concerns about a rare, inch long fish called the Borax Lake Chub living in the 10-acre lake. Environmentalists say the lake also is important to trumpeter swans, snowy plovers, white-faced Ibises and other water-fowl species, as well as an unusual 2-foot reptile called the long/nosed leopard lizard.

In 1993, several environmental groups unsuccessfully appealed to stop Anadarko from drilling test wells near the lake. They included the Sierra Club, the Wilderness Society, the Portland Audubon Society, Oregon Trout and the Oregon Natural Desert Association.

Later that year, the Nature Conservancy purchased the lake from two local ranchers to protect the chub and wild life living around the water. The nonprofit land brokerage paid $320,000 for 320 acres, which included Borax Lake.

According to blueprints for the plant, it would use geothermal water to heat another fluid that would spin a turbine and generate electric power. Afterward, the geothermal water would be pumped back into the underground reservoir.

No steam of gases would be vented into the atmosphere, according to Anadako's project planners. The underground water exceeds 170^{o}F at the bottom of the 100-foot deep lake, and steam produced under pressure reaches 306 degrees.



Anadarko officials have said the plant would employ 17 to 20 workers, with low-profile buildings and probably could not be seen with the naked eye from the 9,670-foot summit of nearby Steens Mountains. (*Oregonian*, April 2, 1996)

Klamath Falls Geothermal District Heating System to Be Evaluated

Klamath Falls has contracted with a geothermal heating specialist to evaluate the city's geothermal district heating system.

Melvin Smith, geothermal supervisor for the city public works department, told members of the Geothermal Advisory Committee, the evaluation should reveal ways to make the system more efficient.

The city has hired Brian Brown, a mechanical engineer from Fort Klamath, to conduct the evaluation at a cost not to exceed $10,000. Brown has worked with the city's downtown geothermal loop almost since it was designed, Smith said.

Brown had begun the evaluation and is expected to work 3 - 6 months on the project.

Brown will examine a telemetric system designed to control the pumps at the city's two geothermal wells located along Old Fort Road. The system is supposed to allow city workers to control the pumps' speed by remote control, pumping more water when more is needed during cold spells, and less water during warm spells.

But the telemetric system has never worked properly, and the pumps have to be operated manually, Smith said. As a result, the pumps often run at a higher speed than is needed, wasting electricity.

Brown will also examine the performance of the heating systems in several downtown buildings. Smith said some building may be receiving more geothermal fluid than needed, resulting in waste.

Smith said the city believes the downtown loop is working at 16 - 18 percent of the capacity, and could serve many more buildings. Brown has been asked to verify that assumption, Smith said.

The system currently serves 22 buildings and provides heating for sidewalks along three blocks of Main Street.

In other business, the Geothermal Advisory Committee heard that a geothermal loop in the Michigan Avenue neighborhood is working far under capacity. Smith said the loop has hookups available for 120 residences, but only 12 acres currently using the system constructed through a federal grant in the early 1980s. (*Herald & News*, March 15, 1996)